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THE CRYOGENIC TENSILE PROPERTIES OF COLD WORKED 20% AND 25% NICKEL STEELS

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Prepared by: E. B. Mikus

GENERAL DYNAMICS/CONVAIR

SUBJECT: "The Cryogenic Tensile Properties of Cold Worked 20% and 25% Nickel Steels."

ABSTRACT: The tensile properties of 20% Ni and 25% Ni alloy steels in the 50% cold worked condition were determined at room and cryogenic temperatures. Properties were determined in both the longitudinal and transverse directions of sheet stock .020" thick. Notched-unnotched ratios were determined at all temperatures. Excellent toughness, as defined by the notched-unnotched ratio criterion, was observed even at -423°F.

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SUBJECT: The Cryogenic Tensile Properties of Cold Worked 20% and 25% Nickel Steel

INTRODUCTION

Within recent months a family of new steel alloys containing 20% and 25% nickel have been developed by the International Nickel Company. Because these alloys have a favorable chemistry and exhibit a suitable strengthening mechanism, they may be excellent alloys for use at cryogenic temperatures.

On this basis an evaluation program of these alloys was initiated to determine the cryogenic properties of these alloys.

MATERIALS

The materials investigated in this program were supplied at no cost by the International Nickel Company and had the following chemistry:

	C	Mn	P	S	Si	Ni	Ti	Al	Cb
Heat 23222 Stock No. 04113	0.007	0.105	0.007	0.002	0.15	20.04	1.27	0.22	0.52
Heat 23223 Stock No. 04113	0.006	0.12	0.008	0.002	0.17	25.33	1.37	0.20	0.54

The alloys were tested in the 50% cold worked sheet condition and were 0.020" thick.

These alloys are hardened by two mechanisms:

1. Precipitation reaction at 800-950°F in which a Fe_x Ti_y type precipitate is formed.

2. Martensitic transformation produced by cold work. The martensite in these alloys does not exhibit tetragonolity because of the low carbon content.

The nickel content of these alloys has a profound effect on the response to heat treatment and cold work.

After a 1500°F anneal, for example, the 25% Ni alloy has an Ms temperature of -150°F compared to +200°F for the 20% Ni alloy. The work hardening response for the two alloys differ appreciably, as well. The 25% Ni alloy strain hardens at a slower rate than the 20% Ni alloy. This characteristic is important when forming operations are employed during fabrication.

RESULTS

The tensile properties of 20% Ni alloy and 25% Ni alloy obtained at room temperature, -100°F, -320°F and -423°F, are presented in Tables I and II. Both longitudinal and transverse directions were employed in smooth and notched specimen configurations.

A summary plot of these data is shown in Figure 1. The results show that both alloys respond to low temperature testing in a similar manner, i.e., the tensile and yield increases as the temperature decreases. The rate at which the yield increases with decreasing temperature appears to be greater than the rate at which the tensile strength increases. This tendency would indicate that brittle failure may be predominate at very low temperatures. However, using notched/unnotched ratio as a criterion, Figure 2, the toughness of these alloys remains high even at -423°F.

The excellent strength and toughness of these alloys make them candidates for cryogenic missile applications. However, before these alloys can be employed in competition with 301 s.s. the room temperature tensile properties needs to be increased. This may be accomplished by one of several heat treatments to which these alloys respond, in conjunction with cold work. If, in this higher strength condition, the alloys remain tough at low temperatures, a further question to be investigated is the weldability of these materials.

CONCLUSIONS

From the data obtained on these materials it appears that the 20% Ni and 25% Ni alloys in the 50% cold worked condition possess excellent notch toughness and tensile strength at temperatures down to -423°F.

In the 50% c. w. condition the alloys do not possess sufficient room temperature tensile properties to compete favorably with 301 ss X FH in a missile skin application.

The response of these alloys to precipitation hardening may offer a solution to the problem of low room temperature tensile properties. However, this solution is only sound if the cryogenic properties of the heat treated alloy have not deteriorated.

TABLE I

Mechanical Properties of 50% Cold Rolled 20% Ni Steel
0.020" Thick, INCO, Ht. #23222

Test Temp	Direction	F_{ty} ksi	F_{tu} ksi	e %	Notched T.S. ksi K_t=6.3	Notched/ Unnotched Tensile Ratio
78°F	Long.	151	165	2	181	
		153	165	2	207	
		157	166	2	209	
	Avg.	154	165	2	199	1.21
78°F	Trans.	151	176	2	183	
		142	175	2	191	
		154	177	2	189	
	Avg.	149	176	2	188	1.07
-100°F	Long.	154	177	-	202	
		147	187	3	205	
		174	184	3	203	
	Avg.	158	183	3	203	1.11
-100°F	Trans.	176		.5	225	
		-			213	
		162	199	.5	225	
	Avg.	169	199	.5	221	1.11
-320°F	Long.	219	229	5.5	244	
		217	227	5.5	247	
		-	223	-	267	
	Avg.	218	226	5.5	253	1.12
-320°F	Trans.	218	244	3.5	270	
		219	238	2.0	266	
		229	243	3.0	-	
	Avg.	222	241	3	268	1.11
-423°F	Long.	-	291	6	355	1.22
-423°F	Trans.	-	-	-	346	-

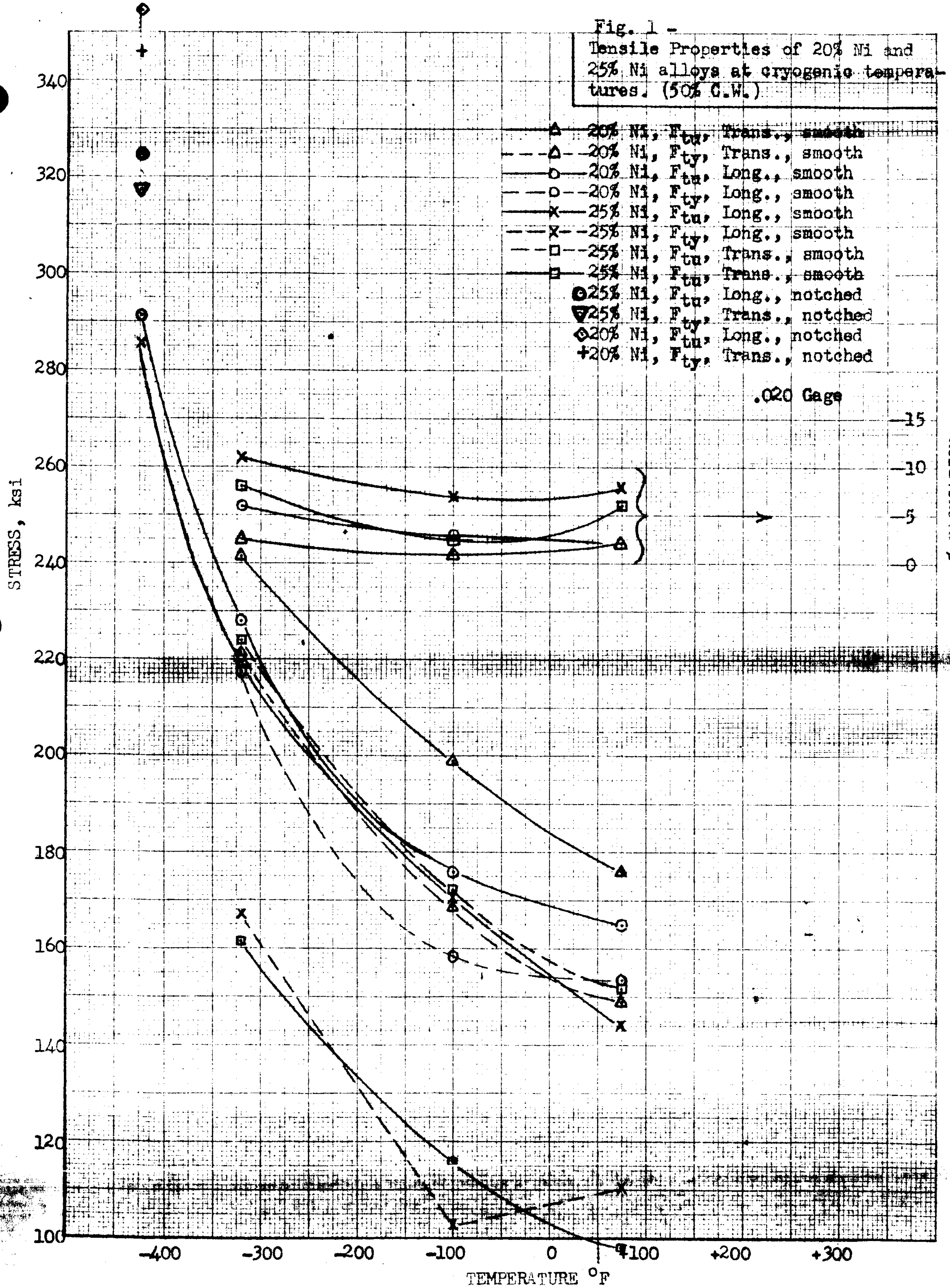

Fig. 1 -
Tensile Properties of 20% Ni and 25% Ni alloys at cryogenic temperatures. (50% C.W.)
20% Ni, F_{tu}, Trans., smooth
20% Ni, F_{ty}, Trans., smooth
20% Ni, F_{tu}, Long., smooth
20% Ni, F_{ty}, Long., smooth
25% Ni, F_{tu}, Long., smooth
25% Ni, F_{ty}, Long., smooth
25% Ni, F_{tu}, Trans., smooth
25% Ni, F_{tu}, Trans., smooth
25% Ni, F_{tu}, Long., notched
25% Ni, F_{ty}, Trans., notched
20% Ni, F_{tu}, Long., notched
20% Ni, F_{ty}, Trans., notched
.020 Gage
STRESS, ksi
% ELONGATION
TEMPERATURE °F
340
320
300
280
260
240
220
200
180
160
140
120
100
-400
-300
-200
-100
0
+100
+200
+300
15
10
5
0

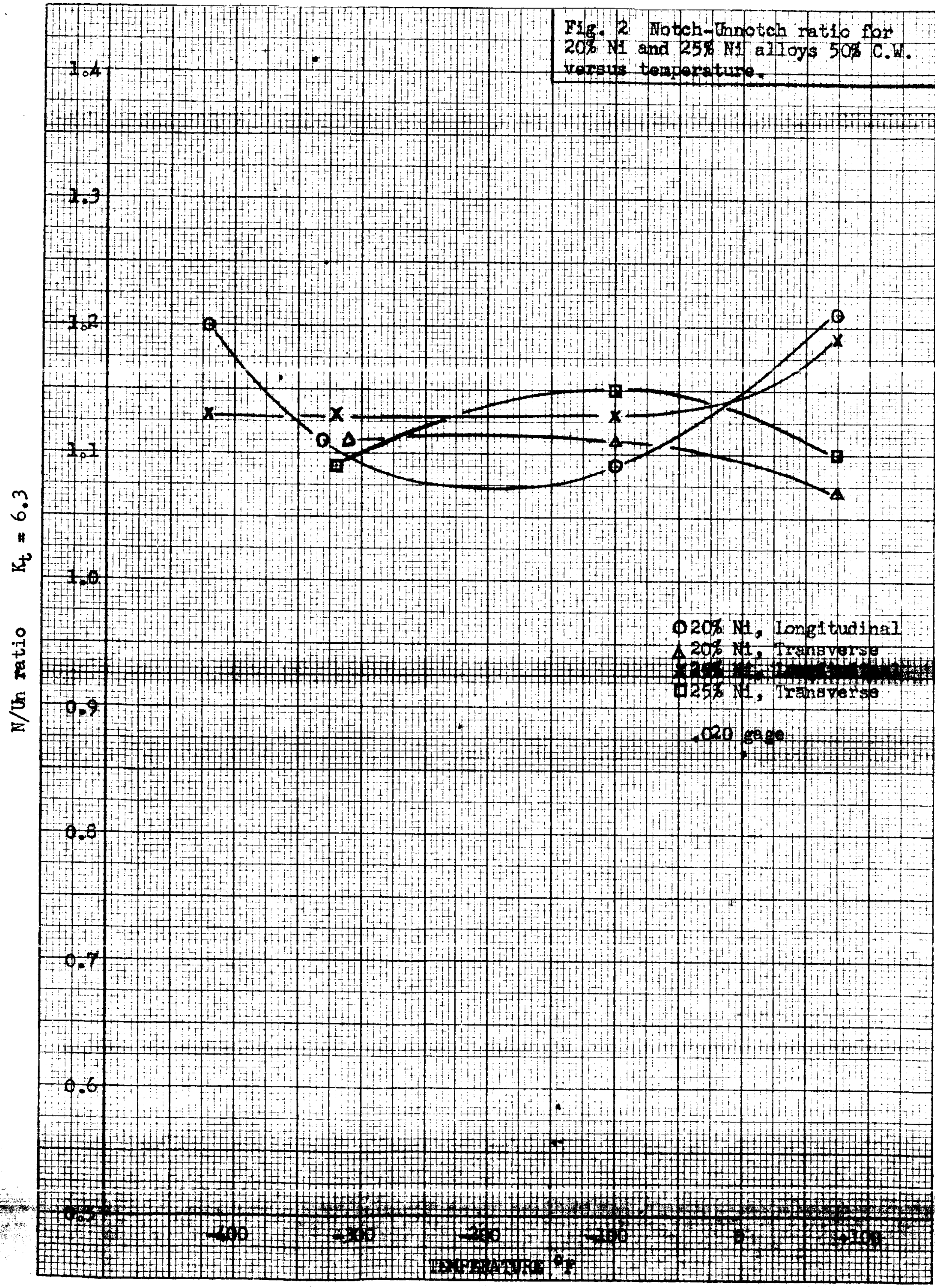

Fig. 2 Notch-Unnotch ratio for 20% Ni and 25% Ni alloys 50% C.W. versus temperature.